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Superstructure-based optimization of biorefinery networks: Production of biodiesel

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Petroleum is currently the primary raw material for the production of fuels and chemicals. Consequently, our society is highly dependent on fossil non-renewable resources. However, renewable raw materials are recently receiving increasing interest for the production of chemicals and fuels, so a new industrial system based on biomass, an inexpensive, abundant and renewable raw material, is being established with sustainability as the main driving force [1]. The processing facilities for the production of multiple products (including biofuels and chemicals) from biomass are referred as biorefineries [2].

The optimal synthesis of biorefinery networks problem is defined as: given a set of biomass derived feedstock and a set of desired final products and specifications, determine a flexible, sustainable and innovative processing network with the targets of minimum cost and sustainable development taking into account the available technologies, geographical location, future technological developments and global market changes.

The problem of optimal design of biorefinery networks is solved in this work through three different stages: (i) synthesis stage, (ii) design stage, and (iii) innovation stage. At the synthesis stage, the considered alternatives are represented in a superstructure, from which a mixed-integer linear or nonlinear programming (MILP or MINLP) problem is derived and solved in order to find the optimal processing network for a pre-defined objective function. Next, at the design stage, the selected processing network is simulated and analyzed and targets for improvement are identified. Finally, a more sustainable design is achieved at the innovation stage by generating innovative solutions that satisfy the targets from the design stage.

The applicability of the proposed approach is shown through a practical case study for the production biodiesel from a variety of feedstock. The different biorefinery processing alternatives are represented in a superstructure and the associated data is collected and stored in a database. Once a specific biorefinery synthesis problem is formulated, the superstructure is reduced in order to include only the relevant alternatives. The reduced superstructure is represented using mathematical models - the modelling approach by Quaglia et al. [3] is used - and solved to find the optimal network for different scenarios.

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